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Insect and Disease Conditions on National Forest Lands in the Blue Mountains 1990 - 1993

By: Donald W. Scott
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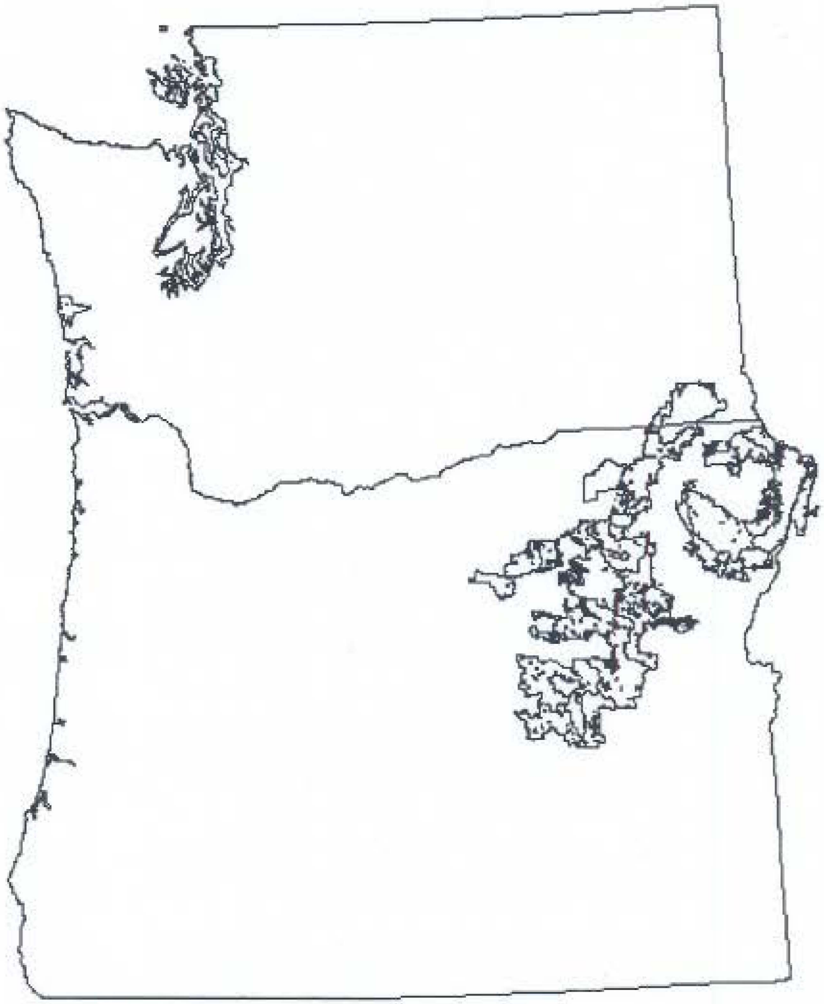

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Donald W. Scott, Zone Entomologist
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La Grande, Oregon 97850

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ABSTRACT

Current insect and disease conditions, and recent insect infestation trends based on aerial insect detection surveys from 1990 through 1993, are reported in this document. Discussions of insect and disease conditions and trends specifically cover the National Forest administered lands within the Blue Mountains Pest Management Zone, including the Malheur, Umatilla, and Wallowa-Whitman National Forests. Though this report addresses National Forest lands, with specific references to Ranger Districts or areas on Ranger Districts within a National Forest boundary, the general trends reported apply to a large extent to BIA, BLM, State, and private forest lands that are within or adjacent to the three National Forests, as well.

Insect populations fluctuate widely most of the time over any given area on any given year. They may reach outbreak levels, and may remain at outbreak levels for several years when conditions are favorable for insect increase, rapid development, and high survival. After 13 years of defoliation of grand and white firs, and Douglas-firs in mixed conifer stands over the Blue Mountains region, populations of western spruce budworm have finally collapsed. Similarly, residual areas experiencing Douglas-fir tussock moth outbreaks of the past several years are now collapsing and are not expected to cause visible defoliation beyond 1994.

In view of the level of crown biomass loss through defoliation following the budworm and tussock moth outbreaks in mixed conifer stands in the Blue Mountains, many are concerned with the survival of true firs and Douglas-firs that not only have been heavily defoliated, but have been stressed by many years of drought, in addition. We address these concerns by providing a discussion of the factors affecting the survival of trees based on our review of the pertinent literature. In essence, the factors affecting the survival of trees that have undergone serious defoliation and drought stress are quite complex, but the literature clearly demonstrates that these conditions can lead to depletion of starch reserves, which can lead to tree death. The level of stored carbohydrates, and the ability to mobilize and use them for replacement of foliage and synthesis of defensive compounds appears to determine the tree's ability to survive the forces that weaken them and threaten their survival.

Spruce beetle populations have finally collapsed after more than a decade of killing spruce of nearly all sizes throughout the northern half of the Wallowa-Whitman. Other bark beetle populations associated with true firs and Douglas-firs are mostly in decline, while pine-associated bark beetles are on the increase throughout the Blue Mountains. Drought-stress and overstocking are believed to be the major factors driving the increase in populations of these beetles. Notable activity by Douglas-fir beetle in the early spring of 1994 in portions of the La Grande Ranger District and North Fork of the John Day Ranger District suggest that populations of beetles are still maintaining high levels within and adjacent to stands of trees severely defoliated by spruce budworm. Beetle-attacked trees that are just now fading, or that have faded over the winter were not identifiable when the aerial survey was flown last summer. Consequently, the survey data for this insect may have underestimated extent of infestations on these Districts. Douglas-fir beetles will likely continue to maintain high populations in certain stands for a few more years in portions of the Blue Mountains defoliated by budworm.

Seldom cyclic like insect populations, forest diseases continue to cause disturbances and affect ecosystem health. Major diseases and their trends are discussed.

INSECT AND DISEASE CONDITIONS ON NATIONAL FOREST LANDS IN THE BLUE MOUNTAINS 1990 - 1993

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INTRODUCTION

Historic and current conditions of insects and diseases affecting forest trees in the Blue Mountains were last discussed in detail as part of the Forest Health Report of 1991 (cf. Gast et al. 1991). Since then, several other efforts have expanded on the 1991 effort, and have analyzed historic and existing conditions on an ecosystem, and watershed basis (cf. Caraher et al. 1992; Everett et al. 1993; O'Laughlin et al. 1993; Schmidt et al. 1993). Most notable among these and pertinent to the Blue Mountains, is the Eastside Forest Ecosystem Health Assessment (see Everett et al. 1993). This report encompassed not only the Blue Mountains, but all of the forested area within the Pacific Northwest Region from the crest of the Cascade Mountain Range east.

Unlike the broader scope of the studies and reports mentioned above, we focus primarily on the insect and disease conditions, and their influence on the forest environment of the Blue Mountains in this report. We discuss and update trends of insects and diseases on Forest Service-administered lands of the Blue Mountains of northeastern Oregon and southeastern Washington; specifically, forested lands of the Malheur, Umatilla, and Wallowa-Whitman National Forests. This report updates insect and disease information for the period 1990 through 1993, providing a broad 4-year "snapshot" of insect and disease conditions and trends in the Blue Mountains. References to "the three National Forests" in this report refer collectively to the Malheur, Umatilla, and Wallowa-Whitman National Forests.

Trees are affected by a variety of biotic and abiotic influences. Windstorms and drought are the most influential weather-related factors of tree and conifer community health. Abiotic influences are related to biotic factors (e.g., insects and diseases). Weakened trees are very often attacked by insects or pathogens that seize upon opportunities to use an abundant resource that has become readily available. Trees may be weakened by abiotic influences such as heavy snows resulting in snow breakage, extreme moisture stress weakening trees on xeric sites, or windstorms resulting in blowdown. Often insects will capitalize on windthrow, breeding in downed trees and then move into healthy trees. For example, recent drought

conditions from 1985 through 1992 and windstorms in 1981, 1991, and 1992, have contributed to the activity of several bark beetle species.

Insects and diseases have traditionally been considered "pests" in that control was aimed at reducing their effects as low as possible. In many situations, this philosophy is still applicable, as with non-native insects and diseases, like the gypsy moth (*Lymantria dispar*), and white pine blister rust (*Cronartium ribicola*), which were inadvertently introduced to this area. Ecosystem management will, often, consider and manage for maintaining an endemic level of insects and diseases consistent with their historic levels of activity that is within the natural range of variability for those plant communities. That is, snags, down trees, trees with decay and witches' brooms, etc., provide habitat for a variety of forest-dwelling flora and fauna including microbes, fungi, invertebrates, and small animals, and cavity-nesting and other birds. Frequently, however, the level of current insect- and disease-created habitat far exceeds what was provided under pre-settlement conditions. Since stand conditions have changed such that insects and diseases are much more active, commonplace, and widespread, and are creating excessive influences we consider "damage," they are now considered pests.

Insect and disease management options and levels will obviously vary depending upon ecosystem management objectives and the nature of the organism, its perceived status at a given point in time, and its ultimate role in ecosystem management, given those management objectives. We will not attempt to provide specific insect and disease management prescriptions, as those have been addressed elsewhere (see Gast et al. 1991). Discussions will be limited to current trends and conditions of insects and diseases. We also explain certain factors affecting the condition of trees, stands, and forests within the Blue Mountains, and the behavior of insect and disease populations relative to vegetative changes since pre-European settlement.

RECENT TRENDS IN INSECT POPULATIONS

Western Spruce Budworm (*Choristoneura occidentalis*)

Trends and Population Levels

After more than a decade of defoliation, western spruce budworm populations have finally collapsed (Fig. 1). Last year, aerial insect detection surveys mapped no visible defoliation by budworm on any forest lands, including non-federal lands, in the Blue Mountains physiographic province.

Budworm populations declined dramatically since 1991 on all three National Forests (Fig. 2). The budworm outbreak that began in 1980 was fueled by widespread mixed conifer stands of overstocked, multistoried, shade-tolerant true fir- and Douglas-fir-dominated species. These stands developed over many decades, mostly in response to the diminishing role of natural, low-intensity, high-frequency surface fires, but also through selective harvesting of seral pines and larch (Agee 1993; Anderson et al. 1987; Carlson and Wulf 1989; Gast et al. 1991; Schmidt 1985; Swetnam and Lynch 1989; Wickman 1992; Wulf and Cates 1987).

Besides an abundance of favored habitat for budworm, a seven-year drought provided favorable climatic conditions in which the budworm could achieve rapid larval development and high survival rates. Assuming no changes in food quality, studies have shown that insects will grow faster and larger, suffer less mortality, and lay more eggs per unit of ingested food, when provided optimal temperature regimes (Mattson and Haack 1987). The same can be said for the major natural enemies of budworm, but their population increases usually lag behind that of their prey or host species. These factors, with relatively low levels of natural enemies to help keep populations of budworm in check, enabled budworm to rapidly increase in numbers and develop to injurious levels in stands.

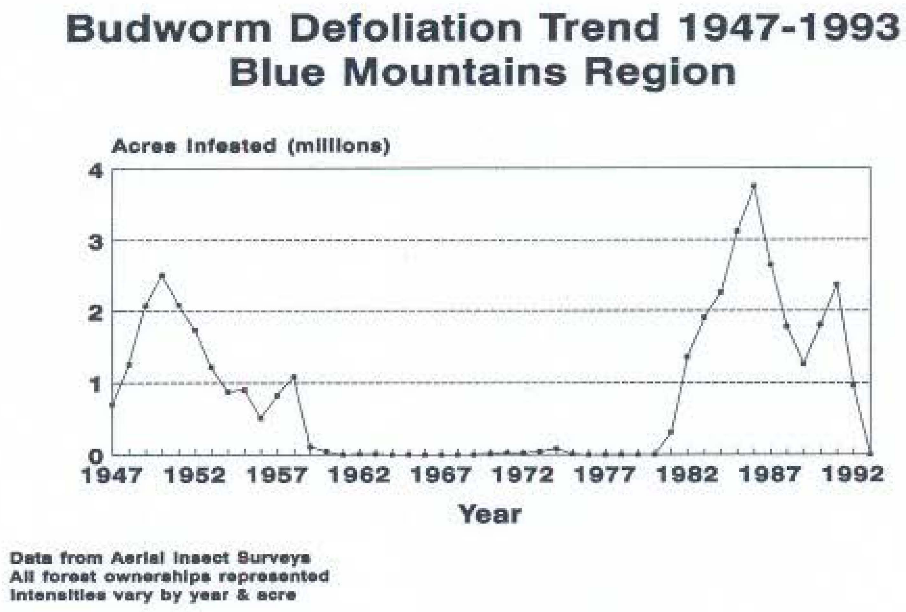

Figure 1. Western spruce budworm trend in the Blue Mountains from 1947 to 1993.

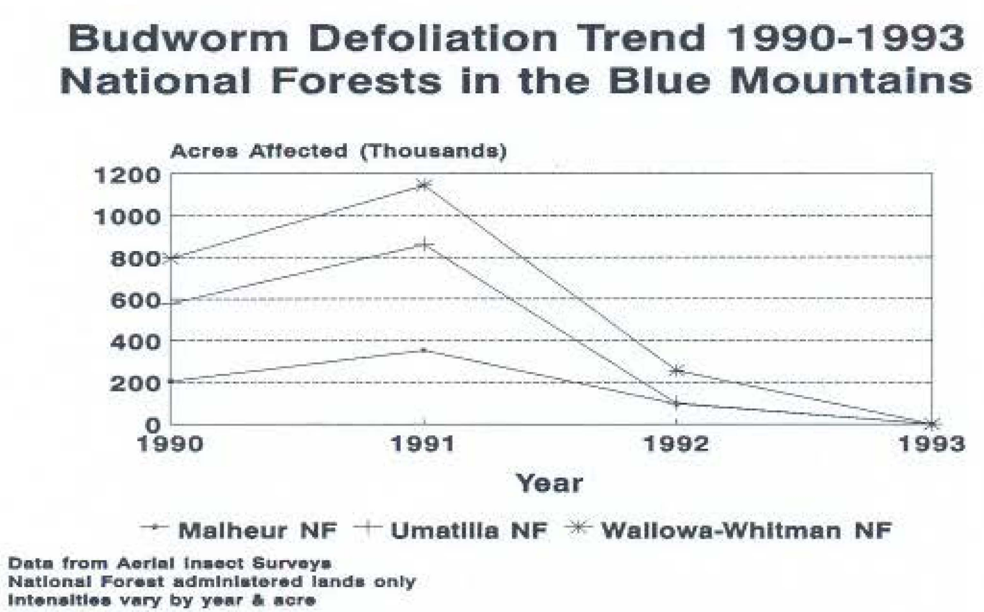

Figure 2. Western spruce budworm trends on the Malheur, Umatilla, and Wallowa-Whitman National Forests in the Blue Mountains from 1990 to 1993.

Over the course of the outbreak, millions of acres of white fir, grand fir, and Douglas-fir dominated stands, along with other minor host species, were defoliated, top-killed, or killed outright by budworm (tree mortality was mostly in the understory). In stands where trees survived budworm defoliation, trees now show substantial radial growth reductions, or have not produced good seed crops for several years due to the destruction by budworm of male strobili, and developing seed cones. In addition, low starch reserves in heavily defoliated trees also contribute to lack of seed crops since carbohydrates, especially reserve starch, and certain amino acids are required for cone-bud development (Allen and Owens 1972). Many other trees have begun to form double or multiple tops because of leader-kill by budworm. In time, some of these trees may manifest major bole deformities.

While these impacts are directly attributed to budworm, and are generally associated with timber resource concerns, many other resource values are also influenced to one degree or another--some positively; others negatively. For example, budworm-caused defoliation and tree mortality affects many resource concerns including: (1) quality of scenic vistas and recreation areas; (2) wildlife habitat and cover; (3) streamside shading; (4) stream habitats; (5) nutrient cycling; (6) old-growth and riparian areas; (7) watershed dynamics (e.g., water yields, interception of precipitation, etc.); and of course, (8) forest fuels condition which influences the risk of wildfire (Gast et al. 1991).

An analysis of results of sampling of budworm populations in 1991 on portions of the Walla Walla RD, La Grande RD, and Wallowa Valley RD found that population densities in 1992 would be high enough to cause moderate to severe defoliation of host trees (Scott 1991). A joint environmental analysis conducted during 1991 by personnel from the Umatilla NF and the Wallowa-Whitman NF found that the affected resources on the analyzed areas would benefit from treatment with insecticides. An Environmental Assessment was subsequently signed by the Forest Supervisors of both Forests, selecting treatment of seven areas with the microbial insecticide *Bacillus thuringiensis* to reduce budworm populations to levels that would be less damaging. Accordingly, the Forests treated 116,344 acres on the Walla Walla and La Grande Ranger Districts (Hadfield 1992), and 70,222 acres on the Wallowa Valley Ranger Districts (Howes and Wallesz 1993).

The severe weakening of budworm-defoliated trees while growing under moisture stress predisposed many stands to attack by various bark beetles. Significant buildups of populations of Douglas-fir beetles, *Dendroctonus pseudotsugae*, in Douglas-firs, and fir engravers, *Scolytus ventralis*, in grand and white firs have occurred in many places in the Blue Mountains. Defoliator outbreaks in mixed conifer stands are often followed by increased attacks by these bark beetles (Berryman 1973; Wickman 1958, 1963, 1978; Wright et al. 1984). Douglas-fir beetles have been largely responsible for killing the larger diameter trees in old-growth and riparian habitats such as on the north end of the Wallowa-Whitman. Similar stands on nearly every ranger district in the Blue Mountains with significant budworm defoliation have had outbreaks of Douglas-fir beetles, as well. The killing of pole-sized true firs by fir engravers that might have otherwise survived budworm defoliation is even more commonly seen scattered throughout the defoliated and drought-stressed stands of the three Forests. Populations of this bark beetle may be even more common than Douglas-fir beetles, even under endemic conditions, due to its close association with root-diseased trees (Hertert et al. 1975; Lane and Goheen 1979; Miller and Partridge 1974).

The collapse of the budworm outbreak began in 1992. Results of sampling budworm populations throughout the Blue Mountains during the summer of 1992 revealed an unexplained loss of budworms between approximately the fourth instar and adult stages. Such occurrences triggering the collapse of outbreaks of spruce budworms, *C. fumiferana*, have been reported from Newfoundland (Raske 1985), and New Brunswick, Canada (Royama 1984).

The spring of 1993 was also exceptionally wet. Winter snow accumulations and abundant spring rains provided a strong rebound--at least temporarily--of local water supplies. Much of the area of the Wallowa, Elkhorn, and Blue Mountains surrounding the Grande Ronde and Baker Valleys measured close to the 30-

year averages for April 1, based on Soil Conservation Service records. The cool moist conditions retarded budworm development and undoubtedly exposed larvae to predation and parasitization by natural enemies for a longer period than in other years of the outbreak. Improved moisture conditions had a twofold effect of providing much needed moisture to drought-stressed trees, and indirectly allowed budworm natural enemies and other mortality factors to help reduce budworm numbers further, and relieve the defoliation pressure on trees.

Refoliation and retention of the new foliage on trees during the spring of 1993 were the net result of the improved moisture conditions and relief of budworm defoliation pressure. Many trees that were nearly dead--stripped of nearly every needle--began displaying a flush of new foliage during the spring of 1993 from latent buds produced the previous year. Survival of many of these trees is still in question, and will be predicated on the degree to which the trees have exhausted energy reserves, can withstand additional seasons of drought stress, and are exposed to secondary insects and pathogens over the next several years.

The two major outbreaks of budworm in the latter half of this century were similar in both outbreak pattern and duration (see Fig. 1). Curiously, both outbreaks showed a bimodal pattern, reaching two distinct outbreak peaks before finally collapsing. Also, each outbreak lasted 13 years: The recent outbreak occurred from 1980 through 1993; the previous major outbreak occurred from 1946 through 1959 (Fellin 1985). Tree ring analysis of old-growth stands in the northern Blue Mountains suggest that budworm outbreaks occurred with a frequency interval of approximately 40 to 50 years before 1900, and at roughly 20 to 30 year intervals since about 1900 (Swetnam and Wickman unpublished data at Tree Ring Laboratory, University of Arizona, personal communication). Given a somewhat regular pattern of outbreak occurrence in the Blue Mountains, the collapse of the recent budworm outbreak may signal an absence of outbreak-level populations in the Blue Mountains for at least several years, and perhaps several decades.

Budworm Defoliation, Drought Stress, and Survival of Trees

Questions have been raised recently in the media, based on results of greenhouse studies with seedlings, about whether budworm defoliation during drought has been beneficial to trees. The argument is made that short-term defoliation (3-4 years) of actively transpiring current-year foliage limits water loss by trees during drought, thereby protecting such trees from succumbing to severe water-stress.

There is indeed a relationship of sorts between defoliation and moisture stress. For example, Wright and Berryman (1978) found that defoliation by Douglas-fir tussock moth, *Orgyia pseudotsugata*, significantly reduced afternoon moisture stress in grand firs during the year that defoliation occurred. However, moisture stress was not significantly reduced in the following two years. This reduction was measured in the area of the tree crown in which the defoliation occurred. The defoliation resulted in reducing the transpirational surface area, thereby lowering water loss from the crown. Interestingly, they observed that trees attacked and killed by bark beetles were not noticeably higher in plant moisture stress than those that survived. They suggested that another factor such as carbohydrate or oxygen deficit might be the mechanism by which defoliated trees became susceptible to fir engraver attacks. In spite of these findings, the authors concluded the following:

> *"Although the hypothesis, that defoliation causes rootlet mortality (Redmond 1959) which results in moisture stress in the years following defoliation, could not definitely be established, the above observations suggested there was a tendency toward increased PMS [Plant Moisture Stress] which may become pronounced under drought conditions."*

In the analogous case of budworm defoliation, cumulative removal of needles by years of defoliation may also result in somewhat reduced afternoon moisture stress in the defoliated portions of the crown; however, this does not prove that defoliation during the drought necessarily protects trees from succumbing to severe moisture stress, or other factors. To be sure, one only has to visit nearly any heavily defoliated mixed

conifer stand in the Blue Mountains to observe the enormous number of dead trees. While mortality rates are quite variable from stand to stand, it is plain to see that severe defoliation kills trees--moisture-stressed or not. Evidence of budworm-caused tree mortality is available from several fronts. First, personal observations have accounted for many areas of budworm-caused tree mortality on both mesic, north-facing slopes in the northern Blue Mountains and Wallowa Mountains, and on xeric pine sites that undoubtedly had moisture deficits in the southern Blue Mountains. We have often used these sites during field-crew training sessions to illustrate effects of severe budworm defoliation. In addition, there are other quantitative studies that clearly show the relationship between budworm defoliation and tree mortality under many differing conditions. For example, long-term impact study plots located in many different stands throughout the Blue Mountains show that the highest rates of tree mortality are directly related to heaviest areas of budworm defoliation (Bruce Hostetler, Forest Pest Management, Portland, OR, personal communication).

The entire question of what mechanism(s) causes defoliated and/or moisture-stressed trees to succumb from any number of factors are closely tied to the energy reserves of the tree. Carbohydrates as starch are major stored products that characterize the primary energy reserves of trees (Waring and Schlesinger 1985; Webb 1981; Webb and Kilpatrick 1993). Starch accumulates in large-diameter roots (Waring and Schlesinger 1985), and is required for several physiological and biosynthetic processes, among which include: (1) the replacement of foliage following defoliation (Parker and Houston 1971); (2) functioning as precursors of secondary plant compounds that form defensive chemicals that help protect plants against predation by animals and microorganisms (Waring and Schlesinger 1985; Wright et al. 1979); (3) being used directly in plant respiration following hydrolysis (Eifert and Eifert 1963; Waring and Schlesinger 1985; Webb 1991); and (4) possibly acting as a regulator or buffer between rapidly fluctuating photosynthesis rates and growth-requiring processes (Webb and Kilpatrick 1993).

The relationship between stored starch resources and a tree's ability to use those resources for refoliation and survival during, or following, periods of stress are complex and do not necessarily assure trees of recovery following defoliation. For example, Kramer and Kozlowski (1960) state that the ability of defoliated conifer trees to refoliate and recover is related, among other things, to the reserve energy as starch in the tree. Webb (1981) added support for the dependent relationship between recovery of foliage following defoliation and starch reserves by showing that crown regrowth is correlated with starch content at the time of budburst. Other studies also suggest stress factors such as defoliation, can apparently block the use and conversion of stored photosynthate (Kozlowski 1969; Kozlowski and Keller 1966; Kulman 1971; Parker and Houston 1971). Therefore, lack of adequate energy reserves or inability to rally the energy reserves stored as starch for the regrowth of essential tissues that necessitate survival may impede a tree's ability to recover from insect-caused defoliation.

Defoliation, itself, can have a significant impact on a tree's starch reserves and its ability to function normally during this period of plant stress. Reduction of starch reserves by insect defoliation is well documented (cf. Bamber and Humphreys 1965; Parker and Patton 1975; Wargo et al. 1972; Webb 1978; Webb 1981; Webb and Karchesy 1977; Webb and Kilpatrick 1976; Wright et al. 1979). The concentrations of these stored starch reserves in the roots, stems, and twigs show the tree's potential to survive attacks by insects and pathogens (Matson and Waring 1984; Ostrofsky and Shigo 1984; Waring and Schlesinger 1985; Wright et al. 1979). Defoliated trees in which starch levels cannot be detected will not recover from defoliation (Bamber and Humphreys 1965; Webb 1981).

If starch reserves are so crucial to a tree's survival following defoliation, and insect defoliation reduces the starch reserves in conifers, then what role does drought play as an environmental component in this physiological and ecosystem process? Does drought favor a tree's ability to survive defoliation by causing trees to regulate moisture loss as some have suggested, or is drought, in fact, detrimental? Drought, or plant moisture stress, has been the subject of interest of plant physiologists, botanists, plant pathologists, entomologists, silviculturists, and foresters since trees and plants have been studied and cultivated. The effects of drought on tree seedlings have been widely known for a long time. Soil moisture conditions, and

the potential effects of drought on seedling survival, are among the biggest concerns of silviculturists and others when re-establishing vegetation on harvest units, burned-over landscapes, or in riparian vegetation restoration projects. These factors are monitored closely to schedule times when planting can occur to optimize tree survival. In overstocked intermediate-size and mature stands in the Blue Mountains, drought has been an important influence on defoliated trees for several years. Outbreaks of bark beetles are especially common in trees predisposed to attack because of extreme and persistent water deficits (Christiansen et al. 1987). Drought, in a mild form in which photosynthesis may still go on may actually increase carbohydrate reserves and levels of defensive compounds because shoot growth requirements abruptly decline under these conditions (Christiansen et al. 1987; Hodges and Lorio 1969; Lorio 1986; Sharpe and Wu 1985). Extended drought, by contrast, halts photosynthesis, initiates a breakdown in leaf protein, depletes starch reserves and defensive compounds, and eventually reduces the size of the canopy (Bradford and Hsiao 1982; Christiansen et al. 1987; Hsiao 1973; Landsberg and Wylie 1983; Pook 1985; Waring and Schlesinger 1985). Many of these changes likely reflect the mechanisms by which these trees become susceptible to attack by secondary insects. Addressing the biochemical processes of trees that have undergone severe drought, Christiansen et al. (1987) hypothesize that the extended large-scale bark beetle outbreaks that frequently follow long periods of drought might be explained by the fact that less carbon is available for defense following the droughty periods.

Therefore, drought of an extended nature, such as experienced in the Blue Mountains, apparently has mostly negative impacts on plants. Overstocked stands made up largely of true firs and Douglas-firs that are poorly adapted to growing on especially unfavorable (xeric) sites, and heavily defoliated by budworm and stressed by multiple years of drought, are sure to have starch reserves nearly depleted, and defensive compounds seriously reduced, given the results reported above. It is no wonder the Blue Mountains have endured the levels of tree mortality from both budworm and bark beetles seen in some of these stands.

To recap, then, the significant studies on the effects of defoliation and drought cited above, clearly show that these factors can lead to depleted starch reserves in conifers--the major energy resource that enables trees to rebuild tissues, produce defensive compounds, refoliate, and survive the processes that weaken them. Depletion of starch reserves leads to tree death. Both defoliation and drought deplete starch reserves in conifers. We submit that while drought may cause trees or portions of crowns to reduce transpirational water loss temporarily under certain conditions, there is no rigorous scientific evidence to suggest that drought--particularly prolonged or severe drought--protects trees during, or following, periods of insect defoliation. Indeed, the evidence all points to the fact that the deleterious effects of drought on trees only compounds the deleterious effects of defoliation, and more than likely hastens tree death directly, or makes them susceptible to secondary bark beetles that eventually kills them.

Douglas-fir Tussock Moth (*Orgyia pseudotsugata*)

Trends and Population Levels

Douglas-fir tussock moth populations increased rapidly on the Wallowa-Whitman NF from suboutbreak levels first discovered on the Pine RD in 1989 (Scott and Mason 1989). Unfortunately, the occurrence of these populations on the Pine and La Grande Ranger Districts, and the Hells Canyon National Recreation Area, could not be aerially mapped due to the presence of considerable budworm defoliation occurring simultaneously over much the same area as tussock moth.

During 1991, those populations on the Wallowa-Whitman that qualified as high enough to merit treatment, were treated with the bacterial insecticide, *Bacillus thuringiensis*. A total of 116,064 acres were treated to reduce population numbers

Lower crown sampling conducted on Ranger Districts throughout most of the Blue Mountains in 1991

found populations to be either low or very low, and remained so in subsequent years except certain locations on the Malheur NF. Defoliation of white firs and Douglas-firs occurred in many stands on the Bear Valley RD near Fields Peak in 1991 and 1992. Though populations of tussock moth could be found over a larger area, the heaviest damage covered an area of approximately 140 acres. Some patches contained trees with defoliation ranging from roughly 40 to 70 percent. Several areas were sampled during 1992, but populations were already beginning to decline. High rates of pupal parasitization were noted during late-summer observations of the area in 1992. Larvae were also killed by parasitic wasps and by nucleopolyhedrosis virus (NPV). By the end of that season, populations had virtually collapsed over most of the area.

While the Fields Peak (Fields Creek)/Beaver Creek area was beginning to have increasing populations, populations at several areas on the Burns RD were also beginning to build up; but, included a much broader area and more locations than on the Bear Valley RD. The areas on the Burns RD included the Coffee Pot/Rattlesnake, Thompson Springs, and Gold Hill. These areas covered approximately 150,000 acres. An additional 40-50,000 acres of tussock moth defoliation were mapped in during the annual aerial survey for insects during the late summer of 1993. Most of the latter area includes stands from South and Southeast of Calamity Butte, North to Jump-off Joe Mountain. Lower crown sampling during 1992 of all areas except the latter mentioned, found relatively high rates of mortality at the pupal stage. Two of the areas (Coffee Pot/Rattlesnake and Thompson Springs had overall pupal mortality rates of 51 and 62 percent, respectively; the Gold Hill area had about 26 percent mortality in the pupal stage. Populations were expected to crash during 1993. Larval sampling during 1993 found outbreak numbers of larvae to still be present in these areas. A visit during September of that same year, however, found high levels of mortality from virus, parasitization, predation, and possibly starvation in some instances. The relatively high numbers of larval cadavers suspended from branches and the leader of many trees were particularly dramatic in depicting the action of the NPV on the population. Egg masses--the few that could be found--were brought back to the laboratory for rearing. All but one contained virus. Obviously this population was indeed crashing, but plans are to monitor these areas again in 1994 to confirm the population collapse.

Spruce Beetle (*Dendroctonus rufipennis*)

Trends and Population Levels

Spruce beetle populations declined throughout the Blue Mountains over the past four years. Populations occurred only on the Wallowa-Whitman NF in significant numbers during this recent outbreak. Minor acreage of spruce beetle-infested Engelmann spruce occurred on the Umatilla NF because of 1991 and 1992 windstorms that blew down spruce and other conifers near Tollgate Guard Station, on the Walla Walla RD.

Spruce beetle trends from 1990 through 1993 are shown in Fig. 3. Populations of spruce beetle declined dramatically on the Wallowa-Whitman NF during 1991 and 1992. Having killed most spruce trees in drainages on the Pine and Wallowa Valley Ranger Districts, and Hells Canyon National Recreation Area, too few large spruce remained to continue to support high beetle populations after 1991. It is difficult to find any live, large diameter spruce anywhere on the north end of the Wallowa-Whitman NF today. The last two years of insect detection flight could account for only 134 acres of trees killed by spruce beetle in 1992 and 102 acres killed in 1993 on the Forest.

Spruce beetle population on the other two National Forests (Malheur and Umatilla) have remained low for the last four years. The Umatilla had 483 acres infested during 1991, probably in association with the blowdown from windstorms. Prompt action to remove the large-diameter, susceptible host trees helped to prevent serious build-up of spruce beetles in stands experiencing blowdown on the Walla Walla Ranger District. The only other areas mapped on either the Malheur or Umatilla National Forests with spruce beetle-killed trees included 8 acres on the Malheur in 1991 and 10 acres on the Umatilla in 1993. These

populations are expected to remain low in 1994.

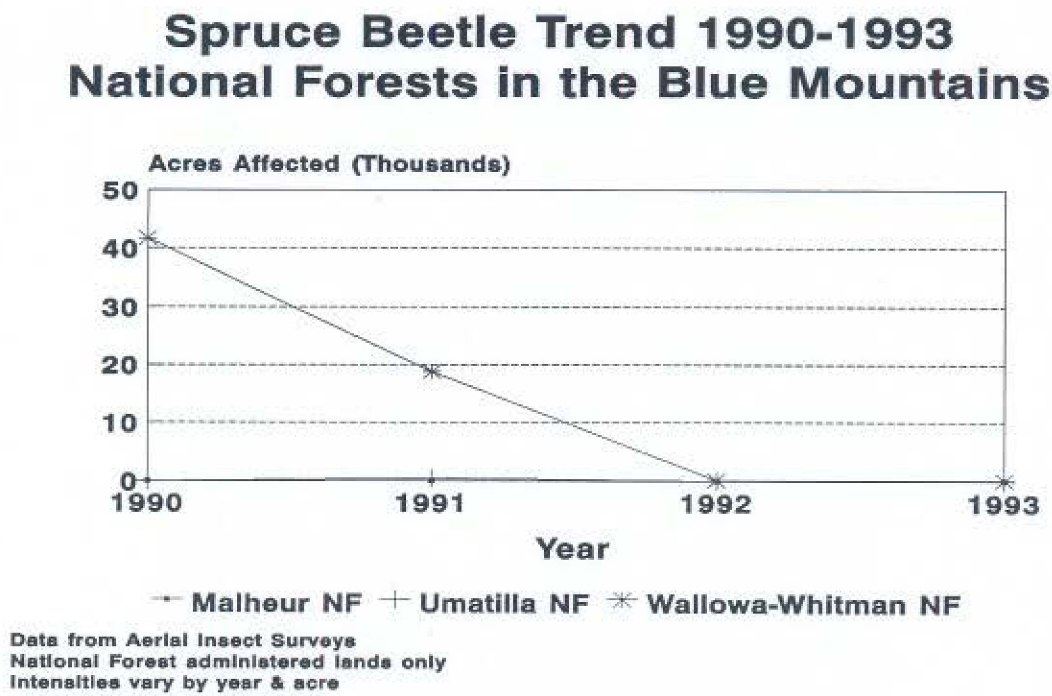

Figure 3. Spruce beetle trends on the Malheur, Umatilla, and Wallowa-Whitman National Forests in the Blue Mountains from 1990 to 1993.

Douglas-fir Beetle (*Dendroctonus pseudotsugae*)

Trends and Population Levels

As mentioned earlier, the susceptibility of large Douglas-firs to Douglas-fir beetle populations in the Blue Mountains has been influenced largely by heavy budworm defoliation and drought-stress. Douglas-fir beetles are normally secondary insects that prefer to attack low vigor and recently dead trees--trees that have been windthrown, struck by lightning, infected with root disease, dwarf mistletoe, or stem decay. Other factors that stress trees, such as drought, defoliation, wildfire, snow breakage and logging operations can cause populations of these bark beetles to build to outbreak levels (Gast et al. 1991).

Large diameter, mature or overmature, trees are those that are at greatest risk of being attacked and killed by beetles. Furniss et al. (1981) found that the average age of trees attacked by beetles exceeded 120 years. Walters (1956) said that Douglas-fir over 150 years old, especially those that are slow growing, are more susceptible than younger, more vigorous trees. Many stands in the Blue Mountains where populations of Douglas-fir beetles increased to outbreak levels and caused substantial mortality--in some cases wiping

out the Douglas-fir component larger than 8 or 9 inches dbh--were stands with large-diameter trees within these age classes, or older. Consequently, mixed conifer old-growth and riparian-associated stands containing a large component of large, old, Douglas-firs were already primed for a Douglas-fir beetle outbreak; all that was needed to encourage beetles to increase to epidemic levels was a major forest disturbance that created a large amount of favorable habitat of weakened trees. Thus, the susceptible stands were created by the interactions of defoliation by budworm, and weakening by drought--especially in overmature and overstocked stands.

Over the past 6 to 8 years, we have observed bark beetle-caused mortality of stands with mature and overmature Douglas-fir on nearly every Ranger District that had also had moderate to high rates of budworm defoliation. In other cases, drought and overstocking, or drought in combination with Douglas-fir mistletoe, had predisposed mature or overmature trees to bark beetles. In contrast to most other areas where Douglas-fir beetles had become epidemic, these were typically stands where budworms had not been present, or did not severely defoliate crowns to significantly weaken trees. The Burns Ranger District, for example, experienced Douglas-fir mortality over the past several years by Douglas-fir beetles under these kind of conditions. In addition, Douglas-fir tussock moth defoliation contributed to increases in Douglas-fir beetles in some stands on the District the last couple of years.

Douglas-fir beetle populations appear to have peaked in 1989--three years following the peak of the budworm outbreak in the Blue Mountains (see Gast et al. 1991). Populations on the three Forests have been declining since 1989 (Fig. 4). Populations in 1993 marked the lowest levels since beetle populations began to increase in 1987. It may seem the Hells Canyon National Recreation Area and the Wallowa Valley Ranger District on the Wallowa-Whitman National Forest were the only areas where significant beetle activity is still occurring, based on the 1993 aerial insect detection survey, but this is not necessarily true as we will show later. The Hells Canyon NRA had 4,241 acres of Douglas-fir beetle-caused mortality mapped during 1993, and the Wallowa Valley RD had 1,161 acres mapped. Total Douglas-fir beetle activity for all Ranger Districts combined on the Malheur totaled 1,048 acres, with over half of that (i.e., 600 acres) occurring on the Prairie City RD. Douglas-fir beetle-killed trees were scattered over 2,262 acres on the four Umatilla Ranger Districts, and over half of that (1,255 acres) occurred on the Walla Walla RD, alone. Douglas-fir beetle populations on the Malheur and Umatilla National Forests in 1994 will probably remain at similar levels to those of 1993. Areas where bark beetles have increased and have been killing small groups of trees each year in stands with heaviest budworm defoliation, will continue to have Douglas-fir beetle-caused mortality until the beetles have killed all or most of the larger diameter trees larger than 9 or 10 inches dbh, based on our observations. We anticipate that with continued pheromone-baiting of trap-trees and aggressive removal of infested trees, populations should continue to decline on the north end of the Wallowa-Whitman this year.

Douglas-fir beetles have killed nearly all mature and overmature Douglas-firs in several severely defoliated mixed conifer stands on the Heppner Ranger District during the budworm outbreak. Observations last summer indicated that populations that built up in response to defoliation and drought now seem to be maintaining populations--though levels have declined considerably--in trees with large mistletoe brooms. We are somewhat concerned about the risk these trees pose to wildfire, as the large, dead, "broomed" crowns of these trees are highly flammable as fuel ladders and could help carry surface fires into the crowns of the surrounding stands. Although these large mistletoed trees enhance ecosystem function by providing roosts, perches, and nesting sites for a number of bird species, and habitat for flying squirrels and other small animals, they may be less important from a wildlife standpoint after they are dead and no longer contain live foliage. Because of the hazard of these dead trees to fire, the value of leaving them in place may need to be re-evaluated.

In contrast to the apparent general decline of Douglas-fir beetle populations throughout much of the Blue Mountains (Fig. 4), populations on portions of the La Grande Ranger District and adjacent areas on the North Fork of John Day Ranger District appear to be increasing again. Our recent observations early this

spring of areas on the La Grande Ranger District found significant levels of Douglas-fir beetle activity along Highway 244, on the slopes within the Grande Ronde River drainage, and scattered throughout stands along the Forest Service 21 Road, and other areas of the District north and east of the 21 Road. Also, the areas on the North Fork of John Day Ranger District along the Forest Service 54 Road, in the vicinity of Lane Creek, had similar levels of Douglas-fir beetle activity apparent this spring.

Much of these areas contain stands that had been severely defoliated by budworm and in which bark beetles had become epidemic, causing considerable mortality to Douglas-firs and grand firs. Douglas-fir beetle populations have continued to kill groups of large-diameter trees associated with the severe budworm defoliation and drought stress each year for the past 4 or 5 years. These beetle populations, having increased to high numbers, now are not only killing trees in the heavily defoliated areas, but seem to be maintaining high populations, and perhaps increasing numbers in stands that were less severely defoliated. Probably, a lot of this tree mortality was not mapped in last year because many of these trees had not faded by the time the aerial surveys were flown last summer. Many tree crowns are only now beginning to turn yellow and red as the trees attempt to draw moisture from soils that are no longer frozen, but they are unable to do so because water conduction through the bole to the crown has been blocked by a blue-stain fungus, *Ophiostoma pseudotusgae*, introduced by the bark beetles when the trees were attacked last year.

Douglas-fir beetle populations may continue to build in overstocked stands with older, large-diameter trees, as long as the drought continues to weaken these trees by reducing stored levels of starch.

Eventually, fewer large trees will remain to sustain high beetle populations. Poor brood production and survival will result as smaller diameter, more resistant trees are attacked by Douglas-fir beetles. The natural resistance of trees will ultimately lead to the collapse of the Douglas-fir beetle epidemic. However, it may take several more years for the collapse of beetle populations to occur.

The increases in Douglas-fir beetle activity on the these portions of the La Grande and North Fork of John Day Ranger Districts are probably not unique. Undoubtedly, there are many other locations with stands of similar conditions to these in the Blue Mountains that also show increased activity of Douglas-fir beetles. The magnitude of this bark beetle activity was probably unprecedented in pre-settlement times. While outbreaks of Douglas-fir beetles were episodic in stands in centuries past, the magnitude and severity of tree mortlality in recent years probably greatly exceeds anything these stands experienced in the past. The association with increased acreage of Douglas-firs along with true firs resulting from fire exclusion and other practices since the turn of this century, and the predisposition of Douglas-firs to attack by bark beetles that results from weakening by budworm defoliation and drought, have created conditions favorable to buildup of beetle populations over broad areas in the Blue Mountains. The ability of these stands to sustain high levels of Douglas-fir beetle activity for an extended period in modern times given past management practices, should not be unexpected.

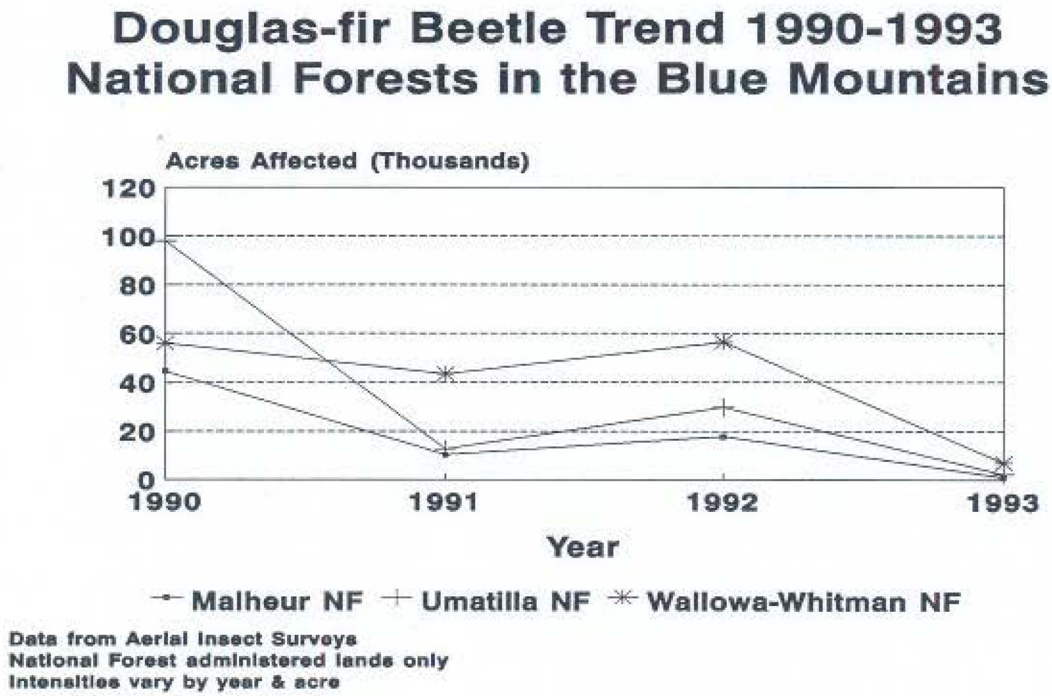

Figure 4. Douglas-fir beetle trends on the Malheur, Umatilla, and Wallowa-Whitman National Forests in the Blue Mountains from 1990 to 1993.

Fir Engraver (*Scolytus ventralis*)

Trends and Population Levels

Much like the Douglas-fir beetle trends, fir engraver trends were highly correlated with budworm defoliation and drought. Beetle populations peaked in 1989, having increased in trees weakened after several years of drought on top of nearly a decade of budworm-caused defoliation (see Fig. 1). The response of populations of fir engravers, which increased near the end of the budworm outbreak, were similar to bark beetle population increases that occurred during the end of the tussock moth outbreak in northeast Oregon and southeast Washington during the 1970's (Wright et al. 1984). Both defoliation and drought are important factors that predispose true firs to attack by bark beetles (Gast et al. 1991).

The major fir engraver population fluctuations and trends (Fig. 5) followed population fluctuations of the spruce budworm in the Blue Mountains (compare Figs. 2 and 5), but beetle increases were delayed by a year or two. The resurgence of budworm populations in 1990 and 1991 was followed to some extent by fir engraver increases on the Malheur NF and Wallowa-Whitman NF in 1992, whereas fir engraver populations continued to decline on the Umatilla (Fig. 5). This again, illustrates the time-lag of bark beetle population response to changes in susceptibility of trees resulting from budworm defoliation and drought.

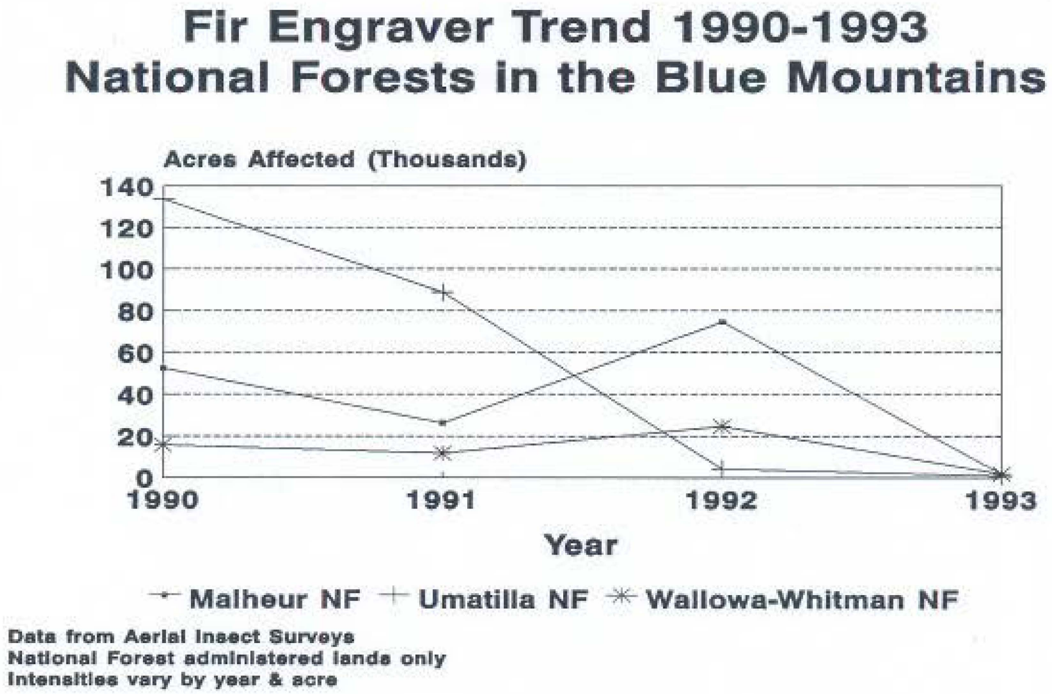

Figure 5. Fir engraver trends on the Malheur, Umatilla, and Wallowa-Whitman National Forests in the Blue Mountains from 1990 to 1993.

With populations of budworm in collapse, and trees beginning to recover, populations of fir engraver should continue to taper off. Lower populations of beetles should result in normally low levels of tree mortality again. Drought, on the other hand, is still a significant factor affecting fir engraver population. A continuation of drought would likely cause beetle populations to continue to successfully kill weakened trees (although at considerably reduced levels) by maintaining good brood survival and elevated population levels in poor vigor trees for a few more years. As factors influencing the susceptibility of trees and success of broods change with improved moisture conditions, reduced competition stress on trees, increased vigor of trees, and unfavorable weather conditions for brood production, growth, and survival, populations should return to endemic levels. At these levels fewer trees are killed each year than now, and the killing of individual branches or occasional tops of true firs, are more typically seen with these endemic populations.

Since tree resistance to attack is related to the amount of current and stored photosynthate that is available for defense (Christiansen et al. 1987; Wright et al. 1979), even the relief of budworm defoliation pressure and drought-stress may not totally eliminate fir engraver beetle attacks in severely overstocked stands, because the carbon stores of trees are affected by tree competition (e.g., Waring et al. 1987). The role of carbon, specifically as carbohydrates, and the actual flux of these compounds for the synthesis of protective chemicals is greatly influenced by the interaction of trees with climate and various components of their environment, including defoliation, drought, and overcrowding that leads to reduced assimilation through shading of foliage (e.g., Christiansen et al. 1987), among others. In view of this, Christiansen et al. (1987) hypothesized that:

> ". . . *the ability of trees to withstand attacks by bark beetles and their associated fungi is linked to the amount of carbohydrates that can be utilized directly for defensive wound*

reactions. Therefore, any environmental factor that restricts the size of the canopy or its photosynthetic efficiency can weaken a tree's resistance."

Though most of the tree killing by fir engraver is now over, overstocked stands, and those where root disease is prevalent, will continue to be susceptible and experience mortality and episodic--although small scale--outbreaks in future years.

Like Douglas-fir beetle populations, the activity of fir engraver beetles will again increase to higher levels the next time another outbreak of tussock moth or spruce budworm defoliates and weakens broad expanses of susceptible timber. Defoliator outbreaks readily create the habitat conditions necessary for bark beetle populations to rapidly build to epidemics. Managing vegetation in stands to increase the proportion of resistant seral species will be crucial to managing both defoliator and bark beetle populations under the ecosystem management approach of the future.

Mountain Pine Beetle (*Dendroctonus ponderosae*)

Trends and Population levels

In the Blue Mountains, both lodgepole pine and ponderosa pine serve as hosts for the mountain pine beetle. During the last major outbreak of this bark beetle from roughly 1967 to 1986 (see Gast et al. 1991), much of the mature and overmature lodgepole pine was killed, and significant--though lesser--areas of second-growth ponderosa pine were killed, as well. Today, little lodgepole pine of the susceptible size (i.e., mostly over 8-inches dbh), age (more than 80 years), and stocking (more than 100 square feet of basal area per acre) remains to support a mountain pine beetle outbreak in that host. Most stands today are younger, smaller in diameter, and typically greatly overstocked. These stands, however, are not susceptible to mountain pine beetles, generally because of the uniformly small diameters and thin bark which are unable to support brood development and survival.

Levels of mountain pine beetle activity in lodgepole pine have been quite low on both the Umatilla and Wallowa-Whitman National Forests over the last four years (Fig. 6). Populations on the Malheur--mostly on the Prairie City RD--increased significantly in 1992; declining only slightly in 1993. The decline of mountain pine beetle trend in lodgepole pine is expected to continue over most areas into 1994 due to the lack of suitable-sized host trees of that species capable of sustaining outbreak populations and resultant high levels of lodgepole pine mortality. Smaller localized epidemics of mountain pine beetle may appear in older stands that typically have received little in the way of vegetation management in the past, based on our observations and experience over the last 3 or 4 years. These are usually areas such as campgrounds or other administrative areas, and include not only lodgepole pine-dominated sites, but those occupied mostly by dense stocking of second-growth ponderosa pines, as well. Some examples of these areas recently experiencing considerable mountain pine beetle activity that we are aware of include campgrounds on the Baker, Unity, Prairie City, Long Creek, Burns, and North Fork of the John Day Ranger Districts, and perhaps other Districts, as well.

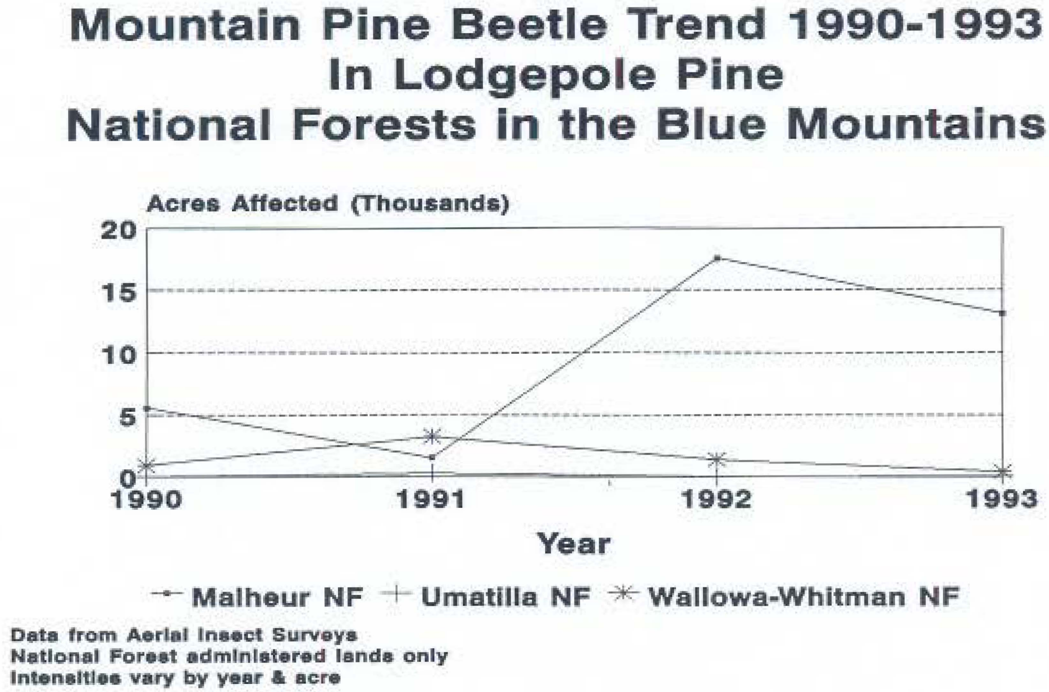

Figure 6. Mountain pine beetle trends for lodgepole pine on the Malheur, Umatilla, and Wallowa-Whitman National Forests in the Blue Mountains from 1990 to 1993.

Many young stands of even-aged ponderosa pine were thinned in the Blue Mountains during the 1970's. After 20 or more years of growth, many of those stands are now composed of pines that have greatly expanded root systems and crown biomasses, and have increased in diameter to where they are competing for soil moisture, root space, and light. Many of these stands are now at a size and stocking level that places them at considerable risk of attack by mountain pine beetles. We often say these stands are "set-up" for a bark beetle outbreak because the conditions of the stand provide the right habitat and environment in which mountain pine beetles can successfully attack trees, produce larval broods, grow and survive, and rapidly increase population numbers in a short time to achieve outbreak levels (usually in a matter of 2 or 3 years). Usually, all that is needed to trigger an outbreak is an event or condition that causes some trees to become attractive to the beetles so that attacks are initiated. A few attacked trees may initially serve as foci to draw in and concentrate many beetles in the susceptible stand. Soon, beetles begin to "spill over" into adjacent trees when "focus trees" become saturated by attacking beetles.

We believe drought-stress is the underlying factor that is presently responsible for weakening trees in many places on the three Forests. Drought stress enables mountain pine beetles to increase in activity and numbers and begin killing groups of trees in overstocked stands of pure, or nearly pure, second-growth ponderosa pine. While ponderosa pines show considerable drought resistance because of their deep-reaching taproot and long and strong lateral roots (Betts 1953), they are subject to the effects of prolonged, severe drought like any other tree species--in time they, too, become weaken, and reach the point where they become susceptible to bark beetles.

The trend of mountain pine beetles in ponderosa pine has been upward the past four years (Fig. 7). All

three National Forests in the Blue Mountains show increases in beetle activity in ponderosa pine, but none quite as dramatic as the Malheur NF, given the scale of figure 7. Nearly 83,000 acres have been mapped with some level of mountain pine beetle infestation on the Malheur National Forest during the 1993 aerial insect detection survey. Most of the acres infested with mountain pine beetles in 1993 were concentrated on the Burns Ranger District, although quite a bit of acreage on the North half of the Malheur NF was mapped with various levels of mountain pine beetles, as well. By comparison, the Umatilla and Wallowa-Whitman National Forests had considerably fewer acres of mountain pine beetles mapped in 1993 with 1,769 and 14,285 acres, respectively. Roughly half of the acres mapped on the Umatilla NF were on the North Fork of John Day RD. On the Wallowa-Whitman NF, most of the mountain pine beetle activity centered on the Baker and Unity Ranger Districts near Dooley Mountain and Black Mountain.

Clearly, most of the mountain pine beetle increases are occurring on the drier pine sites of the central and southern portions of the Blues. However, it is equally clear that the influence of drought on any overstocked stand of ponderosa pine has increased the susceptibility of these stands to bark beetles. That these beetles can increase at an alarming rate under ideal conditions, and result in considerable mortality to the pine resources (cf. Pitman et al. 1982; Sartwell 1971), suggests stand management practices of thinning overstocked stands before beetles have an opportunity to increase would be prudent, under the circumstances.

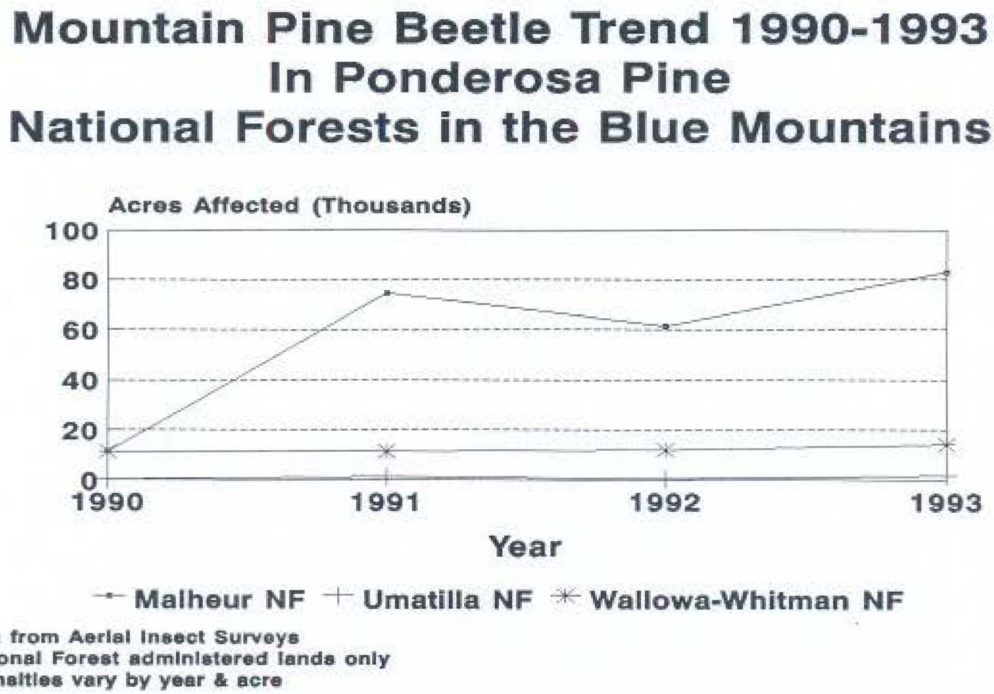

Figure 7. Mountain pine beetle trends for ponderosa pine on the Malheur, Umatilla, and Wallowa-Whitman National Forests in the Blue Mountains from 1990 to 1993.

We believe the current conditions of overstocking and locally high populations of beetles will help to

maintain outbreak levels of mountain pine beetles for several years. Populations of beetles have been slowly building in overstocked stands for several years, but over the last couple of years we have witnessed a much more rapid buildup of beetles in some locations. Typically, outbreaks in ponderosa pine develop slowly (Sartwell and Stevens 1975). After an outbreak begins, the subsequent number of infested trees increases to a level of about 30 to 150 trees per acre per year; reaching this level by the third to fifth year, then declining after that (Sartwell 1971). An outbreak will often run its course from onset to collapse within ten years, but individual outbreaks can last up to two decades (Pitman et al. 1982). Over this period, the bark beetles can kill as much as 60 percent of the trees and 80 percent of the stand volume (Pitman et al. 1982). The loss of future fiber volume, negative effects on non-timber resource values, and the increased risk of stand-replacing wildfire are typically associated with this level of bark beetle activity. Thinning prescriptions in second-growth ponderosa pine stands reduce competition, increase vigor, improve tree growth, and provide various degrees of resistance to mountain pine beetles. Appropriate thinning levels have been recommended by Pitman et al. (1982).

Western Pine Beetle (*Dendroctonus brevicomis*)

Trends and Population Levels

Western pine beetles are often associated with mountain pine beetles in killing of pole- and small sawlog-size ponderosa pines; but, they are also well known as the primary insect mortality factor in overmature, veteran ponderosa pines. During the times when old-growth ponderosa pines were still abundant, one well-known entomologist, in his treatise on the insect enemies of California pines and their control, termed the western pine beetle, ". . . *California's most destructive forest insect*" (see Keen 1928).

Prolonged drought resulting in tree moisture stress, along with overstocking of pine stands, has led to increased susceptibility of ponderosa pines to western pine beetles in much the same way they have become susceptible to mountain pine beetles the last 4 or 5 years. Indeed, the increasing trend of acres infested by western pine beetles on the three National Forests (Fig. 8) also follows much the same patterns of infested acres mapped for mountain pine beetles in ponderosa pine in 1993 (compare Figs. 7 and 8). Western pine beetle populations, especially on the Malheur NF, increased significantly between 1991 and 1992; whereas, bark beetle population increases on the Umatilla and Wallowa-Whitman were considerably less dramatic (Fig. 8).

As with the mountain pine beetle in ponderosa pine, most of the western pine beetle activity on the Malheur NF also occurred on the Burns Ranger District during the 1991-1992 seasons, and during 1993. The Prairie City Ranger District also had a fair amount of acreage infested with western pine beetle in 1993. Rapidly increasing beetle populations on the Malheur NF resulted in beetle-killed pine areas increasing from 1,832 acres mapped in 1991 to 73,598 acres mapped in 1992, and an additional 78,764 acres mapped in 1993.

By comparison, infested acres on the Umatilla and Wallowa-Whitman National Forests increased during the 1991 to 1992 period at a much lower rate than increases on the Malheur NF for this period. Aerial surveys of the Umatilla NF showed the acreage infested by western pine beetles increased from 322 to 905 acres in the 1991 and 1992 survey years, and increased to 2,295 acres in 1993--about half of which was on the Heppner RD. During this period, western pine beetle populations on the Wallowa-Whitman National Forest increased from 264 acres in 1991 to 2,012 acres in 1992, and 10,309 acres in 1993. The Baker and Unity Ranger Districts were the locations on the Wallowa-Whitman NF where most of the western pine beetle activity was mapped during the aerial insect detection survey.

The increase in western pine beetle populations the past couple of years shows the increasing trend of bark beetles in our pine stands throughout the Blue Mountains region. This again points up the need to thin

overstocked pine stands before beetle populations start building up, reach outbreak proportion, and cause unacceptable levels of tree mortality.

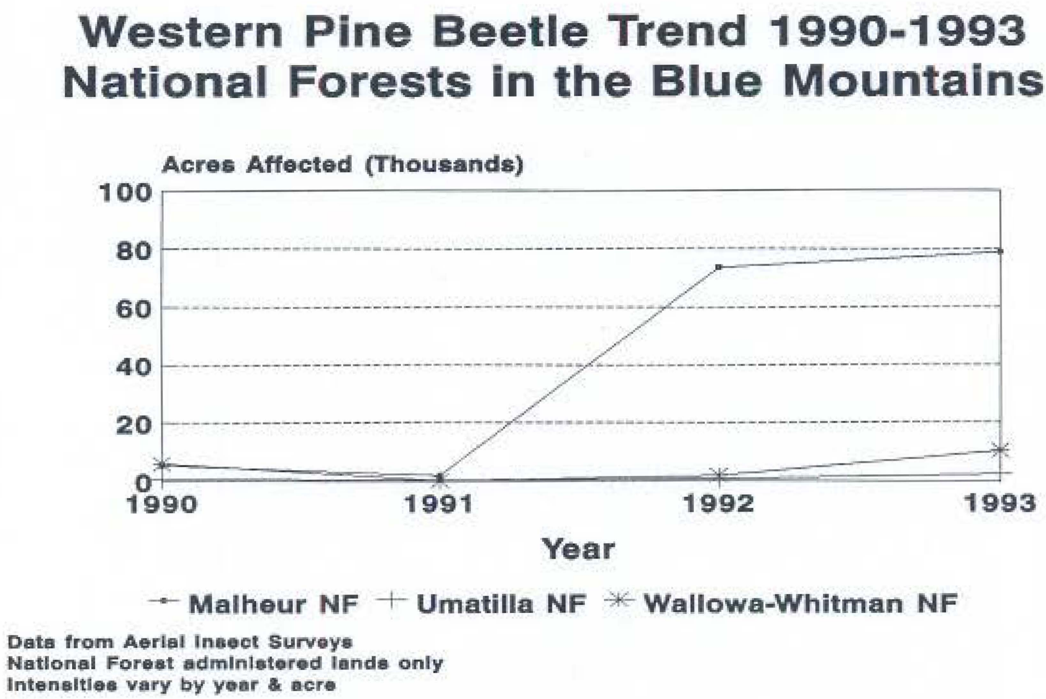

Figure 8. Western pine beetle trends on the Malheur, Umatilla, and Wallowa-Whitman National Forests in the Blue Mountains from 1990 to 1993.

Pine Engraver (*Ips pini*)

Trends and Population Levels

The pine engraver is another bark beetle that is typically found in association with populations of mountain pine beetle and western pine beetle in ponderosa pines, and in association with mountain pine beetle in lodgepole pine. Usually, though, pine engravers will kill thickets of lodgepole or ponderosa pine saplings or poles within the vicinity of recently created accumulations of untreated thinning or logging slash (Livingston 1979).

Populations often build to outbreak during droughty years, particularly whenever the average precipitation for the period April to September is 90 percent or less than normal (Dolph 1971). Besides drought, Dolph identified three other conditions that foster pine engraver outbreaks: (1) High beetle populations; (2) an abundant amount of suitable or fresh slash; and (3) a stagnated stand of trees having poor vigor. Where these conditions exist in pine dominated communities in the Blue Mountains, we can expect to see varying levels of pine engraver activity.

Like other bark beetle species in pine associations, pine engravers have been on the increase in several locations on the three Forests in the Blue Mountains the past 3 or 4 years. Though pine engraver

populations are low compared to western pine beetle and mountain pine beetle, the recent trends show an upswing in areas infested (Fig. 9). The largest increase from a previous year was mapped for the Wallowa-Whitman NF in 1993. Increases were roughly fourfold over those of the Umatilla and Malheur National Forests during 1993. Most of the pine engraver beetle activity was on the Baker RD; much of it associated with the large areas of mountain pine beetle activity near Dooley Mountain and Black Mountain, and around Phillips Reservoir. A total of 4,591 acres was mapped as infested with varying levels of pine engraver beetles over the whole Wallowa-Whitman National Forest in 1993. Acres mapped as infested with pine engraver beetles on the Umatilla and Malheur National Forests in 1993 were 1,139 acres and 1,388 acres, respectively.

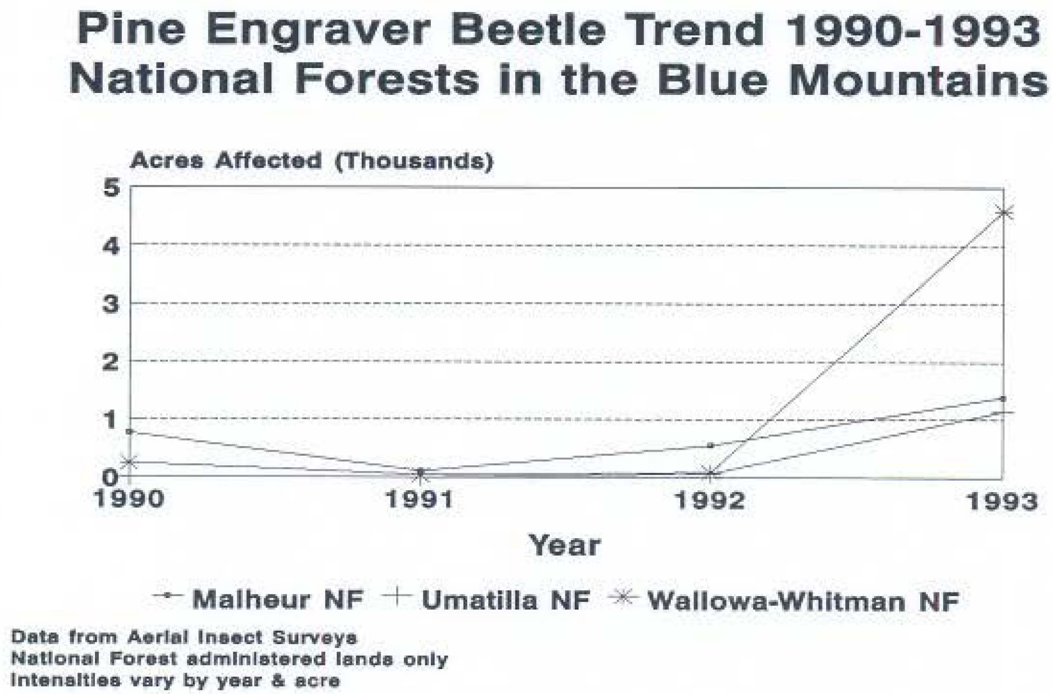

Figure 9. Pine engraver beetle trends on the Malheur, Umatilla, and Wallowa-Whitman National Forests in the Blue Mountains from 1990 to 1993.

Normally, year to year tree mortality from pine engravers is low. Most of this mortality is to sapling and pole-size thickets near units that have been recently thinned or logged. Moisture deficits that create plant moisture stress in the upper bole of larger trees may be critical in detecting trees that will be top-killed by pine engravers, as this portion of the bole is the location where pine engraver attacks are first initiated (Dolph 1971).

It is difficult to predict what populations of pine engraver beetles are going to do in the next year or two. Clearly there is a relationship between percent of normal precipitation during spring and early summer months, and pine engraver population increase (Dolph 1971; Livingston 1979; McGregor et al. 1977), but other factors are involved as well, including those mentioned above plus soil type, stocking, age, site, and level and nature of stand disturbance (Dolph 1971). At best, we can suggest that with another relatively dry winter (1993-1994), and without abundant precipitation from April through July, we can probably anticipate

another "Ips" year--as years with high pine engraver beetle-caused tree mortality are so called. Usually, pine engraver beetle outbreaks are short-lived, lasting no more than a generation or two; therefore, we do not expect beetle populations, and related tree mortality from these beetles, to remain high for long. Management of slash created during thinning and harvesting activities can significantly reduce pine engraver-related tree mortality. Dolph (1971) and Livingston (1979) list several factors to consider during tree harvesting and thinning activities to reduce potential problems from pine engraver beetles.

STATUS OF FOREST DISEASES

Tree disease activity has steadily increased in most all cases since the late 1800's. Documented increases for insects draw upon the annual aerial survey flown by the Region. No such data base exists for tree diseases. Tree diseases are not readily observable from the air. Mortality caused by root diseases has usually been attributed to bark beetles (which are usually involved). Even permanent plot and stand exam information are not considered reliable. Most of the valid information on status and trends of forest diseases is from observations made by District and Forest silviculturists, Regional and Zone pest specialists, and research scientists, and includes some specific pest biological evaluations and administrative studies done in the past (e.g., Schmitt et al. 1991).

DWARF MISTLETOES

There are four dwarf mistletoes in the Blue Mountains: Those that occur on Douglas-fir (*Arceuthobium douglasii*), larch (*A. laricis*), ponderosa pine (*A. campylopodum*), and lodgepole pine (*A. americanum*).

Western Dwarf Mistletoe

Dwarf mistletoe in pine can be found on all Districts in the south part of the Wallowa-Whitman and all Districts on the Malheur. Highest incidence is on the Baker and Unity Districts (Wallowa-Whitman NF) and the Prairie City and Bear Valley Districts (Malheur NF). In the Blue Mountains, incidence is believed lower than the Region-wide average reported by Bolsinger (1978) of 26 percent.

Western dwarf mistletoe has intensified most noticeably on the dry, pine plant community series sites; those that continue to maintain a pine understory with the absence of fire. Damage is high on these stands and those more mesic sites that are unable to regenerate pine due to grand fir or Douglas-fir encroachment and competition. In this later case, dying pines are not being replaced and tend to speed succession toward late seral condition.

Pine dominated stands have diminished and shade tolerant fir stands have replaced these on many sites in the Blue Mountains. There is actually a decrease in infection where fir has invaded pine sites since hosts are now a much lower proportion of stand components on these sites.

Increase in mistletoe, as well as radial spread, has been steadily occurring when pine remains dominant in the understory. Fire once played the major role in keeping this disease in check, since infected trees are much more apt to be removed in fires due to persistent lower broomed limbs that serve as fuel ladders, or in their already weakened condition, succumb to bark beetles following the fire.

Douglas-fir Dwarf Mistletoe

Dwarf mistletoe in Douglas-fir is found throughout most of its host type. Thus, it is common and severe on all Districts in the Blue Mountains. Certain plant communities are likely to have always been heavily infected, and others are believed to have become severely infected in the last century. Of all the mistletoes,

Douglas-fir is becoming the most damaging--spreading and intensifying on sites where it had never been a problem in the past.

In Douglas-fir series and the more moist pine plant communities, Douglas-fir was always a stand component. Usually stocking has increased with progression of succession, since fire, usually periodic fire on fairly frequent intervals of underburning, kept succession skewed toward its early stages. Reduction or removal of fire has caused four (4) very crucial changes:

1. Exclusion of fire has allowed Douglas-fir to greatly intensify on sites once kept primarily in pine stocking, especially in the understory. Typical stands may have once had a dominant pine and minor fir overstory, and a very lightly-stocked understory; also, pine dominated. Now fir completely stocks the understory and it has become heavily infected from overstory sources.

2. Douglas-fir is invading pine communities where previously it could not become established. Dwarf mistletoe is following the expansion of its host's range via radial tree-to-tree spread, and inadvertent spread by birds.

3. Stocking levels in all cases have increased dramatically. With increased stocking and associated abiotic stresses, dwarf mistletoe-infected trees are more likely to be killed by secondary or associated insects, such as the Douglas-fir beetle. These beetles can build to epidemic status using these stressed trees. In 1993, we identified high endemic beetle activity in the Starkey area, and on the Umatilla NF, mostly on mistletoe-infected fir.

4. Mistletoe-infected firs are excellent fuel ladders as they often have dead needles and resin-soaked tissue in these brooms that are frequently near the ground. Upon ignition, heavy stocking of these trees will easily carry the fire into the crowns of associated old remnant pine, creating a stand replacement event where once underburns were the norm.

These stand condition scenarios are very common and they alone account for one of the greatest changes in stand conditions in recent years. Tens of thousands of acres in the Blue Mountains are posed for stand replacement fire where open, pine-dominated conditions once prevailed. Watershed and fisheries resources are at grave risk where large expanses of fire-susceptible stands occur.

Larch Dwarf Mistletoe

Larch dwarf mistletoe is found almost everywhere its host occurs. Some occasional stands or portions of stands are free of infection. This is the result of stand history; very hot stand replacement fires that removed old, normally fire resistant residuals will create these uninfected expanses.

Before suppression of fires, larch was a major early seral component in most mixed conifer mesic communities. Given its very thick bark, those trees that matured survived periodic fire and some stand replacement fires. Following these disturbances, larch frequently regenerated very heavily. Overstory larch infected with mistletoe served as a source of infection to the developing understory. Mortality gradually intensified and eventually killed mature survivors. As the overstory died, these were usually replaced by understory larch on nearby disturbed sites with a younger age class. Larch dwarf mistletoe seemed well adapted to the fire and successional ecology of these communities, and served as a creator of snags.

With fire suppression, larch regeneration has come to nearly an abrupt halt as most sites have not had recent disturbance. Overstory trees are dying from mistletoe without an adequate replacement of larch stocking.

Loss of seed producing potential occurs as remnant larches lose their crowns when brooms break as trees slowly die. To summarize, the current situation, mistletoe has intensified in existing host trees but larch regeneration is considerably lower than historical levels.

Lodgepole Pine Dwarf Mistletoe

Lodgepole dwarf mistletoe is scattered throughout its host type, but does not reach the intensity found in the Central Oregon Plateau. Pure stands of lodgepole in lodgepole communities are most apt to maintain and develop highest rates of infection. This is due to a continuing dominant component of host stocking on the site through the cycle of regeneration-maturation-beetle kill and fire; with a few scattered infected individuals that survive the beetles and fire then serve to spread infection throughout the stand over the next 100 or so years. Due to the 1970's mountain pine beetle epidemic in the Blue Mountains, many thousands of acres of lodgepole stands were salvaged and mistletoe-infected residuals were removed or girdled. As a result, incidence of infections has been reduced from historic levels.

ROOT DISEASES

There are several root diseases that affect stands. Several of these are very common and affect stand structure. Several others may be of concern on specific sites and a couple will be mentioned.

Annosus Root Disease

There are actually two different annosus root diseases (*Heterobasidion annosum*), in pine (P-Type), and in true fir (S-Type).

Annosus in pine is found mainly in the dry pine plant community series sites, most often on fairly poor sites. Annosus spreads by airborne spores produced from conks of the fungus that fruit in old stumps and around the base of infected pine. Spores infect freshly-cut stumps or wounds, and the developing fungus colonizes the woody tissue and roots over several years. Pine growing near these sources of infection may become infected in time as roots contact infected material (usually at least 20 years since initial adjacent stump infection).

Infected sites can be found in several areas, but the Burns and Bear Valley Districts (MAL) seem to have the highest incidence. This is simply because of the prevalence of high hazard low quality sites on those Districts.

Incidence of infection and associated mortality has increased in relation to past timber harvests not having used preventive measures. In the last five years, treatment of freshly-cut pine stumps with borax has become standard policy on many Districts to prevent this disease from becoming established. We can expect to see some continued increase for another two decades, then the incidence should level off. Since this root disease is confined to specific sites, it is easily prevented, and usually does not cause more than moderate damage; thus, it's not a high risk disease.

Annosus in grand fir is similar in biology and spread. Grand firs near fir stumps are at risk. Incidence of grand fir stump infection is very high; averaging at least 90 percent. Infection of adjacent fir occurs across all sites where fir is a component.

The occurrence of this disease in fir is rapidly increasing and becoming visible, especially on sites with several entries. Fir harvesting, or inclusion in the sale volume only became common in the late 1960's. For that reason, annosus disease in fir stands is still appearing and already established centers are expanding. Stump treatment with borax is recommended wherever fir will be managed in the future. Currently, about 4 percent of the fir stocking is affected by annosus. These include the wet, mesic fir

communities, and others where resource values require managing this species outside of its natural range of variability.

Recent re-registration of granular borax will allow Districts to again secure and use this product. Some recent concerns over the safety to applicators and also insect populations and wild and domestic ungulates are believed to be unwarranted. A Regional (FPM) borax position paper addressing concerns with borax is due to be released the spring of 1994. Alternative methods of stump treatment are being investigated but technologies for effective application are limited.

Armillaria Root Disease

Armillaria root disease, caused by *Armillaria ostoyae*, is the most common, widespread, and damaging root disease in the Blue Mountains. It is found on a variety of sites from dry pine communities to mesic spruce-subalpine fir stands. This native disease has a wide host range and is most severe on sites dominated by grand fir. Stands may have scattered single tree infections or large dramatic root disease centers. All Districts in the Blue Mountains have this root disease and most have examples of large active root disease centers. An estimated 2 to 3 percent of trees in grand fir-dominated stand types are currently infected or have been killed by Armillaria. Douglas-fir and pine communities have less than 2 percent, and larch, less than 1 percent of their trees infected.

Armillaria was believed to always have been an endemic stand inhabitant, but several factors are causing it to become increasingly prevalent and severe.

1. Dramatic increases in primary host stocking (grand fir, Douglas-fir) on sites historically occupied by less susceptible conifers (pines, larch).

2. Exclusion of fire is allowing a gradual change in soil chemistry believed to increase virulence and activity of Armillaria.

3. Soil damage, compaction, and associated residual conifer damage is very much responsible for much of the increase in Armillaria occurrence and virulence that have occurred in recent years. Cat-yarding in repeated partial cut entries, especially during the wet season, is the main culprit.

Laminated Root Rot

Laminated root rot is not found in many areas of the Blue Mountains in abundance, but several areas have relatively high incidence. The La Grande RD (Wallowa-Whitman NF), especially on Mt. Emily, has the highest level of infected sites on the Wallowa-Whitman. Smaller areas in Ladd Canyon and near Mt. Harris, as well, and on the Wallowa Valley and Baker Districts have confirmed infected sites. The Umatilla NF has an even higher level of infestation. Only one area on the Malheur NF is known to harbor this pathogen; this 100-acre area, in the Fox Creek drainage on the Long Creek District, was discovered several years ago.

Affected sites will have most of the host species infected. Depending upon the size of the tree when infected and the time since infection, either mortality, butt rot, or growth loss may result.

Laminated root rot seldom spreads via spores, although that mechanism is responsible for occasional long-distance spread. Most spread is on already infected sites where root contacts between hosts and host regeneration tends to allow for perpetual host infestation. Stand conditions that allow maximum spread are late seral species dominance and lack of early seral species. Thus, fir dominance on pine and larch sites will allow for this pathogen to increase in disease virulence with radial spread at rates of 1 to 2 feet per

Blackstain Root Disease

Blackstain root disease was recently discovered to be a major cause of mortality on mostly pole-to small sawlog-size ponderosa pine in the southern portion of the Malheur NF. Previously, these disease pockets were attributed solely to bark beetles, which are usually also present. Blackstain has been found on Starr Ridge and further south, becoming increasingly more common on the south portion of the Burns District, east of Highway 395. Blackstain in pine causes pockets of mortality that spread both via insect vectors (root-feeding beetles and weevils) and across root to root contacts.

While several obviously older long-established centers are common, we are especially concerned with the prevalence of young, recently-visible, 1 to 3 tree mortality groups. These are considered satellite centers, having spread via insects some distance from older infected trees. We expect most of these to continue to increase in size and probably again multiply. Stand disturbance, some required to reduce overstocking, is known to exacerbate blackstain spread. We also believe that the change in ecological processes (removal of periodic fire) may be contributing to disease virulence. While the Burns District is mapping occurrence of blackstain, we don't know total acreage infected, but are sure that the infected sites and total area are steadily increasing, and will continue to increase given current stand conditions.

Other Root Diseases

There are other root diseases that can be found at low incidence over wide areas; others may only affect trees on certain sites. The following are two of the more common of these other root diseases.

Schweinitzii root and butt rot is quite common in Douglas-fir and larch. Most other conifers are affected, but at much lower levels. This disease is found in most older stands and usually acts as a weak pathogen, infecting trees and slowly causing decay in the lower butt. Incidence and assorted effects are believed to be decreasing, largely due to losses of many older Douglas-fir and larch because of other factors including bark beetles and dwarf mistletoe.

Tomentosus root and butt rot is very common in stands of spruce. Almost all spruce sites have a high incidence of this pathogen. Older trees will have several feet of decay in the lower bole and very frequently these trees fail or break in the lower butt because of advanced decay. Older spruces have higher incidence of disease and higher levels of decay. Since most older Blue Mountain stands of spruce have succumbed to spruce beetles in the last 12 years, tomentosus levels have plummeted, but will again slowly build along with the developing maturity of spruce stocking.

<u>STEM DECAYS</u>

Indian Paint Fungus

Indian paint fungus causes internal heart decay of grand fir boles. Advanced stages of decay will usually extend from the butt to the upper stem, especially on moist sites and on older trees that have multiple infections. Similar sites with stands of older trees may have very high incidence of decay; frequently more than 80 percent decay, in terms of total fir volume.

Incidence of decay is ever increasing with the increasing prevalence of grand fir stocking in the Blue Mountains. Highest incidence is on sites traditionally mixed conifer with larch and Douglas-fir components. Pine sites also have Indian paint decay in the invading grand fir, but at lower levels than on mesic sites. Highest incidence of this decay is in trees suppressed for decades before release. Disturbed sites, especially where plenty of wounding occurred during selective harvest entries, typify sites prone to

high levels of decay. Since these site and stand factors are contributing to ever increased hazard levels, we can expect the level of this specific decay to continue to increase. Our observations show that incidence of decay in fir currently is about 5 percent in pine/Douglas-fir dominated communities, increasing to 10 percent in mesic mixed conifer stands.

RUSTS

White Pine Blister Rust

White pine blister rust is an introduced disease of 5-needle pines. In the Blue Mountains, western white pine and white bark pine are affected. Blister rust causes girdling cankers to develop that result in dead branches, dead tops, and very frequently, tree mortality. Western white pine stocking in the Blue Mountains has been reduced from historical levels. This is the direct result of selective removals in harvesting, blister rust-caused mortality, and poor regeneration rates because of reduced fire occurrence.

A review of the blister rust situation in the Blue Mountains in 1993 showed the incidence of infection increased on a south-north gradient. Stands near Dixie Summit on the Malheur have a relatively low level of infection. In the northern part of the Blue Mountains, white pine becomes more common, as does the level and mortality caused by blister rust. Selection of select pine genotypes, breeding and propagation of resistant trees at Dorena Seed Orchard, is planned to restore pine stocking to historical levels in the Blue Mountains.

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